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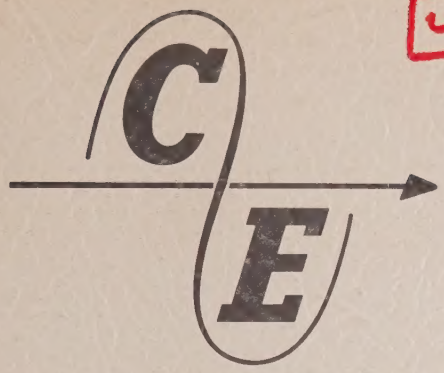

Cushman Electronics, Inc.

MANUFACTURERS OF PRECISION ELECTRONIC INSTRUMENTS

166 SAN LAZARO AVENUE
SUNNYVALE, CALIFORNIA

MP MASTER
MA31805

OPERATING-SERVICE MANUAL

PFM-2

PRECISION FREQUENCY MODULATOR

CUSHMAN ELECTRONICS, INC.
166 SAN LAZARO AVENUE, SUNNYVALE, CALIFORNIA
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PFM-2 SPECIFICATIONS

FM DEVIATION

Range: Continuously variable to ± 18 Kc
Accuracy: ± 4% of full scale (as indicated on either of the MCM-5 deviation ranges)

MODULATING FREQUENCY

Internal: 1 Kc & 2.08 Kc
External: 60 cps - 20 Kc
(Input, 2 volts RMS across 10K for 18 Kc deviation)

OVERALL DISTORTION: Less than 2%

CALIBRATOR ACCURACY:

1st null: 5.0 Kc ± 2%
2nd null: 11.55 Kc ± 2%
3rd null: 18.0 Kc ± 2%

POWER REQUIREMENTS: 3 watts (from MCM-5)

DIMENSIONS: 7" High, 7 1/4" Wide, 7 1/2" Deep

NET WEIGHT: 4 pounds

SHIPPING WEIGHT: 6 Pounds

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SECTION 1

FUNCTIONAL DESCRIPTION

1-1 GENERAL

The Cushman Model PFM-2 Precision Frequency Modulator is designed specifically for use with the Cushman Model MCM-5 Multi-Channel Frequency Monitor to extend the usefulness of the MCM-5. With the PFM-2, any of the MCM-5's 23 frequency channels may be frequency modulated. Complete flexibility in choice of modulating frequency and amount of deviation is provided. For receiver general alignment and testing, the PFM-2 provides an internal modulating frequency of 1000 cps. In addition, external signals may be used to supply any modulating frequency between 60 cps and 20 Kc. Deviations from 0 to 18 Kc may be obtained. The amount of deviation is continuously variable by use of coarse and fine controls on the front panel of the PFM-2 and is indicated on either of the two deviation ranges on the MCM-5 meter.

The PFM-2 may also be used as a calibration standard for deviation measurements. An internal modulating frequency of 2080 cps is generated for this purpose. At the calibrating frequency, three precise carrier nulls at 5, 11.55 and 18 Kc are obtained for checking the accuracy of the MCM-5 deviation meter ranges. The nulls are indicated on an external voltmeter or microammeter connected to the DC METER terminals on the front panel of the PFM-2.

A carrier null at any precise amount of deviation between 1 Kc and 18 Kc may be indicated in the same manner by connecting the proper external modulating frequency to the PFM-2.

1-2 CONSTRUCTION

The PFM-2 is sturdily constructed in a compact enclosure, convenient for either portable or bench usage. All circuits are completely transistorized and mounted on firmly supported printed circuit boards to assure trouble free performance. Operating controls are front-panel mounted and designed to provide extreme simplicity of operation: Three basic functions are selected by a single switch, and deviation adjustment is made through ganged coarse and fine potentiometers. An external DC meter and audio signal source may be connected to the unit through standard, paired, banana jacks on the front panel.

Connection to the MCM-5 is made through a single, four-foot, flexible cable that is permanently attached to the PFM-2. The cable is terminated in an eight-pin polarized male connector.

1-3 UNPACKING AND INSPECTION

Special instructions are not required for unpacking the PFM-2, other than to inspect the instrument for signs of possible shipping damage. As soon as possible after delivery the unit should be operated. If the instrument is damaged, or fails to operate properly, file a claim with the transportation agency, or, if insured separately, the insurance company. (See Warranty on last page).

1-4 INSTALLATION

CAUTION

THE PFM-2 SHOULD BE CONNECTED TO THE MCM-5 ONLY WHEN THE MCM-5 IS OPERATING AS AN FM SIGNAL GENERATOR OR WHEN CALIBRATING THE DEVIATION METER ON THE MCM-5. FOR ALL OTHER MCM-5 FUNCTIONS, THE PFM-2 MUST BE UNPLUGGED.

The PFM-2 is installed by simply plugging the eight-pin male connector into the auxiliary output receptacle located on the side of the MCM-5. The connector is polarized and can fit into the receptacle in only one way.

When the unit is installed, 6.3 volts AC is automatically applied from the MCM-5, energizing the PFM-2 circuits. This voltage will be within the proper tolerance for the PFM-2 operation so long as the line voltage to the MCM-5 is maintained within the specified limits of 104 to 130 volts AC, 50 to 400 cps. The red indicator lamp on the front panel of the PFM-2 illuminates when the unit is in operation.

Since the PFM-2 is completely transistorized, no warm up period is required for its operation; the unit is ready as soon as it is plugged in. The MCM-5, however, requires 30 minutes for the crystal oven to reach operating temperature.

SECTION 2

OPERATING INSTRUCTIONS

2 - 1 FREQUENCY MODULATOR

To frequency modulate the MCM-5 signal generator output on any of its 23 channels, the MCM-5 must first be set up as normally done for generating a prescribed frequency. Assuming that the MCM-5 has been turned on for the required warm up period of 30 minutes and is ready for operation, steps A, B, and C below are performed BEFORE THE PFM-2 IS PLUGGED INTO THE UNIT.

A. Select the carrier channel by rotating the CARRIER FREQ. SELECTOR control to the required position between 1 and 23.

B. Rotate the function switch to HARM. AMP. TUNE and adjust the HARMONIC AMPLIFIER TUNING control to obtain a peak indication on the meter.

C. Turn the function switch clockwise to its next position, ZERO FREQ. ADJ., and adjust the ZERO FREQ. ADJ. control until the meter reads zero (mid-scale).

D. Install the PFM-2 by plugging its cable into the right-hand rear side of the MCM-5 (see Section 1-4).

E. Rotate the MCM-5 function switch to the CARRIER FREQUENCY ± 10 Kc position and zero (mid-scale) the meter by adjusting the 5 MC. ADJ. control on the PFM-2.

NOTE: When the PFM-2 is used for the first time, the range of the 5 MC. ADJ. potentiometer may be insufficient to zero the meter, or an extreme position off the mid-point may be required. For best operation, the 5 MC. ADJ. knob should be in the mid-position with the meter zeroed. This can be obtained by placing a thin non-metallic screwdriver in the access hole on the top of the unit and adjusting the variable capacitor in the PFM-2 until a mid-scale zero is read.

F. Rotate the MCM-5 function switch to either the 18 Kc FM DEV. or 6 Kc FM DEV. positions. This allows the amount of deviation of the FM output to be read directly on the MCM-5 meter.

G. Place the PFM-2 selector knob to one of the three positions for the desired modulation conditions:

The INT. MOD. position supplies an internally generated modulating frequency of 1000 cps. This frequency is very useful for general alignment and testing of receivers (see Section 3-5).

The CAL. position supplies an internally generated modulating frequency of 2080 cps. This frequency is normally used for calibration of the MCM-5 (see Section 2-2).

The EXT. MOD. position allows external single or multiple tone frequencies to be injected into the PFM-2. This provides FM modulation of the desired carrier at any audio frequency from 60 cps to 20 Kc. When using the PFM-2 in this manner, the product of the FM deviation in Kc and the modulating frequency in Kc should not exceed 200. This will ensure optimum performance and minimum distortion. The external signal is connected through the EXT. MOD. INPUT jacks (see Section 2-3).

H. Set the amount of deviation desired by turning the two concentric DEVIATION ADJUST knobs. (The outside knob is the coarse adjust and the inside knob is a vernier adjust). The amount of deviation can be read directly from the MCM-5 meter.

I. Rotate the MCM-5 function switch to the SIG. GEN. position. The output of the MCM-5 is now an FM signal with the deviation set in step H.

NOTE: When the PFM-2 is used with the MCM-5, the level of the output is typically double that of the unmodulated (CW) signal generator output. Consequently, the MCM-5 attenuator controls are forced out of calibration. If exact calibration of these controls is essential, the following procedure can be used to recalibrate the attenuators:

(1) Disconnect the PFM-2 and transmit a CW signal to the receiver under test.

(2) Choose a convenient signal reference level (for example the 20 db quieting level) and note the AGC voltage on one of the unsaturated stages on the receiver's IF strip.

(3) Connect the PFM-2 and set the DEVIATION ADJUST controls for zero deviation (fully counterclockwise).

(4) Adjust the GEN. LEVEL SET control on the MCM-5 until the same AGC voltage as was read in Step (2) as indicated.

By performing this procedure, the PFM-2 is caused to supply the same energy to the receiver as the CW output of the MCM-5. This fixes the total power into the receiver to a constant level, regardless of the amount of deviation.

2-2 DEVIATION CALIBRATOR

When used as a deviation calibrator, the PFM-2 provides three precise carrier nulls for checking accuracy of the MCM-5 deviation meter ranges. Calibrator checks are performed in the following manner:

A. Perform Steps A through F as outlined in Section 2-1, placing the MCM-5 function switch in the 6 Kc FM DEV. position.

B. Connect a vacuum tube voltmeter or a 20,000 ohms-per-volt DC meter to the DC METER jacks on the PFM-2.

C. Place the PFM-2 selector knob to the CAL. position and turn the DEVIATION ADJUST knobs fully counterclockwise. Observe the DC meter reading as between 1 and 3 volts, nominal.

D. While observing the DC voltmeter, slowly increase deviation by turning the DEVIATION ADJUST knobs clockwise. Observe that the meter reading decreases toward zero. Check that the first null on the DC meter occurs at 5 Kc deviation (as read on the 6 Kc deviation scale on the MCM-5).

E. Change the MCM-5 function switch position to 18 Kc FM DEV.

F. Increase deviation and check that a second null occurs at 11.5 Kc. Further increase deviation and check that the third null occurs at 18 Kc (maximum reading on 18 Kc deviation scale).

2-3 EXTERNAL CALIBRATION INPUT

A carrier null at any precise amount of deviation between 1 Kc and 18 Kc may be indicated in the same manner as described in Section 2-2 by placing the PFM-2 function switch to EXT. MOD. and connecting the desired external signal to the EXT. MOD. INPUT jacks. The required input frequency for a given deviation is determined by simply dividing the deviation by 2.41. For example, to obtain a null at 1.5 Kc of deviation:

$$*\text{External Mod. Freq. (cps)} = \frac{\text{Deviation (cps)}}{2.41} = \frac{1500}{2.41} = \frac{622 \text{ (cps)}}{}$$

*This formula is applicable for calculating only the first carrier null. In the example, as the deviation is increased beyond 1.5 Kc, several additional nulls will be indicated but will normally be ignored for calibration purposes. If required, these nulls may be calculated by the method explained in Section 3-5, C.

SECTION 3

CIRCUIT DESCRIPTION

3-1 GENERAL

The PFM-2 Precision Frequency Modulator is composed essentially of a five megacycle voltage controlled oscillator and an audio generator. The audio generator supplies either a 1000 cps or 2080 cps signal for frequency modulating the 5 Mc. Selection of the modulating frequency is provided by a three position function switch which connects the circuit RC networks for generating the proper frequencies; the INT. MOD. position selects the 1000 cps modulating frequency, and the CAL. position selects the 2080 cps modulating frequency. When the switch is placed in the EXT. MOD. position, the audio oscillator is bypassed and an external audio signal from 60 cps to 20 Kc may be used to frequency modulate the 5 Mc. The external signal is applied to the unit through the EXT. MOD. INPUT jacks.

Deviation is controlled by two ganged DEVIATION ADJUST potentiometers. These potentiometers vary the amplitude of the input audio signal to the five megacycle oscillator and thus control the amount of deviation. The front panel outer knob is a coarse control and the inner knob a fine control. Adjustment of the deviation potentiometers allows frequency deviations from 0 to 18 Kc.

The five megacycle oscillator signal is modulated by biasing a variable capacitance diode in its feedback circuit with the audio signal. Stability of this oscillator is ensured through employment of an automatic frequency control (AFC) loop, which "locks" the oscillator to the discriminator in the MCM-5. The AFC voltage is controlled in the PFM-2 with the 5 MC. ADJ. potentiometer. This potentiometer allows the AFC to be accurately set for an exact 5 Mc carrier output. The FM output of the PFM-2 is applied through the coaxial cable to the MCM-5.

For calibration purposes, the PFM-2 employs a five megacycle bandpass filter to reject all but the carrier frequency from the FM output. The filter uses a lattice type configuration with two crystals and associated capacitors to obtain a narrow bandwidth centered at 5 Mc. A DC output proportional to the carrier frequency energy is thus supplied from the filter to the DC. METER jacks. A DC voltmeter or sensitive DC ammeter may be connected to these jacks for observing the carrier energy. With no modulation, the meter will read maximum when the oscillator frequency is exactly 5 Mc.

Under frequency modulation conditions the DC output will vary in accordance with the amount of carrier frequency energy at any given deviation. At certain deviations, the carrier energy will be zero and all the signal power will be in the sidebands. This can be observed as discrete nulls on the DC meter. The nulls can be calculated for any modulating frequency by using a Bessel Function relationship (See Section 3-5, C).

Input voltage to the PFM-2 is 6.3 volts AC and is supplied from the MCM-5. The front panel indicator lamp illuminates when this voltage is supplied to the unit. An internal power supply provides regulated -15 volts DC for energizing the PFM-2 circuits.

3-2 AUDIO OSCILLATOR

A phase-shift oscillator using transistor Q102 generates the internal 1000 cps and 2080 cps modulating signals. Frequency selection is accomplished through function switch S101, which connects to the oscillator feedback networks. When the switch is in the first position (INT. MOD.), an RC network is selected which generates an output at 1000 cps. When the switch is in the second position, the selected RC network generates an audio voltage at 2080 cps. Transistor Q101 is an emitter-follower used for impedance matching of the feedback network to the base of Q102. Potentiometer R113 sets the level of oscillations, and is used to control the distortion of the audio signal.

The audio oscillator is disconnected from the circuit when the function switch is placed in the third position (EXT. MOD.). An external audio signal may then be applied to the unit through the EXT. MOD. INPUT jacks.

The audio signal taken from the collector of Q102, or externally, is applied through the DEVIATION ADJUST potentiometers, R115 and R116, to amplifier Q103. The potentiometers allow the amplitude of the audio signal to be accurately adjusted. R115 is the coarse control and R116 is the fine control. Transistor Q103 amplifies the audio signal to the proper modulating level. The amplifier gain is set with potentiometer R123.

3-3 FIVE MEGACYCLE OSCILLATOR

Transistor Q201 is used in a modified Colpitts oscillator to generate the 5 Mc carrier frequency. This frequency is determined by inductor L201 and its associated capacitors in the oscillator feedback network. Capacitor C205, which is part of the feedback network, provides fine adjustment of the 5 Mc carrier frequency.

Modulation is accomplished by use of capacitor-diode CR201 in the oscillator network. This component functions as a variable capacitor whose capacitance changes as a function of the audio voltage applied across it. The voltage-capacitance characteristics of CR201 is non-linear, however, and is compensated by VECO varistor R122, which has a non-linear characteristic in the opposite direction. Exact balance of linearity is accomplished by adjusting R123.

When the audio signal is applied across the capacitor-diode, its capacitance change is proportional to the audio signal level. The modulator frequency thus varies to more or less than 5 Mc in accordance with the audio signal. This FM output is taken at the emitter of Q201.

Stability of the five megacycle oscillator is provided through an AFC feedback from the MCM-5 discriminator output. This AFC provides the oscillator with the stability of the temperature controlled discriminator. The AFC voltage is injected through P101-2 and P101-5 and is applied across the capacitor-diode. Potentiometer R206 (5 MC. ADJ.) allows exact adjustment of the AFC so that CR201 is biased at a quiescent level which produces 5 Mc from the oscillator. If the oscillator frequency starts to drift, the AFC voltage level will change in a direction to compensate for the drift. The RC time constant of the AFC circuit is such that it will not respond to rapid changes caused by audio modulation.

The FM output at the emitter of Q201 is capacitively coupled to transistor Q202, which operates as a five megacycle Class C amplifier. Variable capacitor C210 in the amplifier tank circuit centers the amplifier's response at 5 Mc. The output of Q202 is applied through the coaxial cable to terminals P101-3 and P101-4 for application to the MCM-5.

3-4 FIVE MEGACYCLE BANDPASS FILTER

The FM output of Q202 is also applied to the base of transistor Q401. This transistor operates as a five megacycle Class C amplifier and provides isolation between the bandpass filter and the FM output to the MCM-5. Variable capacitor C402 and the primary of transformer T401 form the amplifier tank circuit. The secondary of T401 feeds into the crystal filter composed of variable capacitors C403 and C404 in series with five megacycle crystals Y401 and Y402, respectively. Each crystal is shunted by a second variable capacitor, C405 and C406, respectively. The crystals operate in a manner so that C403 and C404 control their resonant frequency and C405 and C406 control their rejection capabilities. Centered at 5 Mc, the -6 db bandwidth of the crystal filter is approximately 200 cps; rejection at 400 cps is at least 40 db.

The paralleled outputs of the two crystals are coupled through transformer T402, whose secondary is tuned to 5 Mc by variable capacitor C407. The 5 Mc signal is then rectified through CR401 and filtered by L401 and C409. This DC output is applied through R407 to the DC. METER jacks.

3-5 DC METER OUTPUT

The DC. METER output of the PFM-2 is used primarily for calibrating the deviation ranges of the MCM-5. Since the narrow bandwidth of the filter allows only the 5 Mc carrier to pass, none of the sidebands will get through (providing the modulating frequency is greater than 400 cps). Therefore, with no deviation, the DC output will be maximum when the oscillator is exactly on five megacycles. Frequencies above and below five megacycles will provide correspondingly lower DC outputs. As the deviation is increased from zero however, the energy contained in the carrier will rise and fall in a manner proportional to a known Bessel Function. The carrier energy, and thus DC output, becomes zero at discrete ratios of deviation to modulating frequency. By monitoring this energy and observing the carrier nulls, the ratio is very accurately determined.

A. DEVIATIONS WITH 1000 CPS MODULATING FREQUENCY

The 1000 cps internal audio frequency is supplied for general receiver alignment and testing. With this modulating frequency six discrete nulls can be obtained as the deviation is increased from zero to maximum. These nulls are summarized in the following table:

DC METER NULLS AT 1000 CPS

NULL	DEVIATION (KC)
1st	2.41
2nd	5.52
3rd	8.65
4th	11.79
5th	14.93
6th	18.07

B. DEVIATIONS WITH 2080 CPS MODULATING FREQUENCY

The 2080 cps internal calibration frequency provides three precise carrier nulls at 5 Kc, 11.55 Kc and 18 Kc of deviation. The MCM-5 meter deviation ranges can quickly and easily be checked at these deviations. (See Section 2-2).

C. DEVIATIONS AT EXTERNAL AUDIO FREQUENCIES

Carrier nulls may be obtained at any precise amount of deviation between 1000 cps and 18 Kc by connecting the proper external modulating frequency to the PFM-2. For any modulating frequency, carrier nulls can be predicted through applications of *Bessel Function constants. These constants are listed below for the first six nulls, and are used in the same manner as described in Section 2-3 for calculating the first null. Thus to calculate the additional nulls, simply replace the number 2.41 in the formula by the constant applicable to the desired null:

$$\text{External Mod Freq (cps)} = \frac{\text{Deviation}}{K}$$

where K is:

2.41	-	first null
5.52	-	second null
8.65	-	third null
11.79	-	fourth null
14.93	-	fifth null
18.07	-	sixth null

*Additional values may be found in standard issues of Bessel Function Tables.

3-6 POWER SUPPLY

The PFM-2 is energized by 6.3 volt AC filament voltage from the MCM-5. This voltage enters the PFM-2 through connectors P101-1 and P101-3. Front panel indicator lamp DS301 illuminates when power is supplied to the unit. Transformer T301 steps up the input voltage to approximately 20 volts. This voltage is then full-wave rectified by diodes CR301 and CR302, and filtered by C301 and C302. The filtered DC is applied to transistor Q301, which acts as a series voltage regulator.

Zener diode CR303 maintains the base of Q301 at an accurately controlled -15 volts. The emitter of Q301 is thus maintained at -15 volts regardless of minor load and line voltage variations. Following Q301, the -15 volts DC is further filtered and then supplied to the circuits of the PFM-2. The filter network also provides isolation between the various circuits receiving voltage from the power supply.

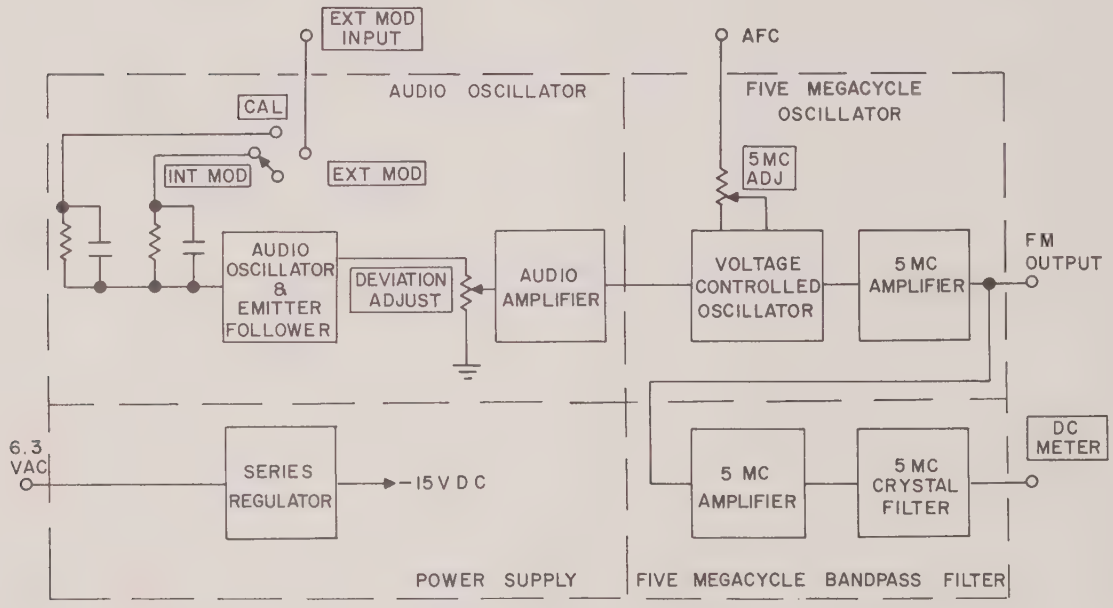


FIG. 1. PFM-2 CIRCUIT BLOCK DIAGRAM

SECTION 4

ROUTINE MAINTENANCE AND CALIBRATION

4-1 GENERAL

The PFM-2 has been designed to provide reliable performance over extended periods of time, and should require a very minimum of service or maintenance. The fully transistorized circuits and selected components have no definite limited operating life and should require no periodic maintenance when used under normal operation conditions.

All adjustment potentiometers and variable capacitors are set at the factory prior to shipment and care has been taken so that the components should not require further adjustments. However, all components are subject to aging and it is recommended that the PFM-2 calibration be checked at least annually.

4-2 AUDIO OSCILLATOR ADJUSTMENTS

NOTE: Before performing the following procedure, the bias voltage on transistors Q101, Q102, and Q103 should be checked. Correct voltages are listed in Section 5-4.

A. Using the PFM-2 as a frequency modulator, perform steps A through F of the operating instructions in Section 2-1.

B. Connect an external audio oscillator (Hewlett Packard Model 200CD or equivalent) to the PFM-2 EXT. MOD. INPUT jacks. Set the oscillator frequency to 1000 cps.

C. Turn the DEVIATION ADJUST outside knob fully clockwise. Set the selector switch to EXT. MOD.

D. Adjust the amplitude of the external oscillator output until 18 Kc of deviation is read on the MCM-5 meter.

E. Connect a distortion analyzer (Hewlett Packard Model 330B or equivalent) across the MCM-5 SCOPE output jacks.

NOTE: A three conductor ring-tip-sleeve type phono jack must be used with the SCOPE jack on the MCM-5. In addition, a DC blocking capacitor and a transformer (Triad A-39A or equivalent) must be placed between the MCM-5 and the distortion analyzer. The wiring is made as shown in Figure 2. To prevent stray 60 cycle pickup from giving false distortion readings, the transformer should be shielded with tin foil or other shielding material, and physically positioned for minimum pickup. With no FM deviation, (DEVIATION ADJUST controls fully counterclockwise) the maximum pickup as read on the distortion analyzer must be at least 50 db down.

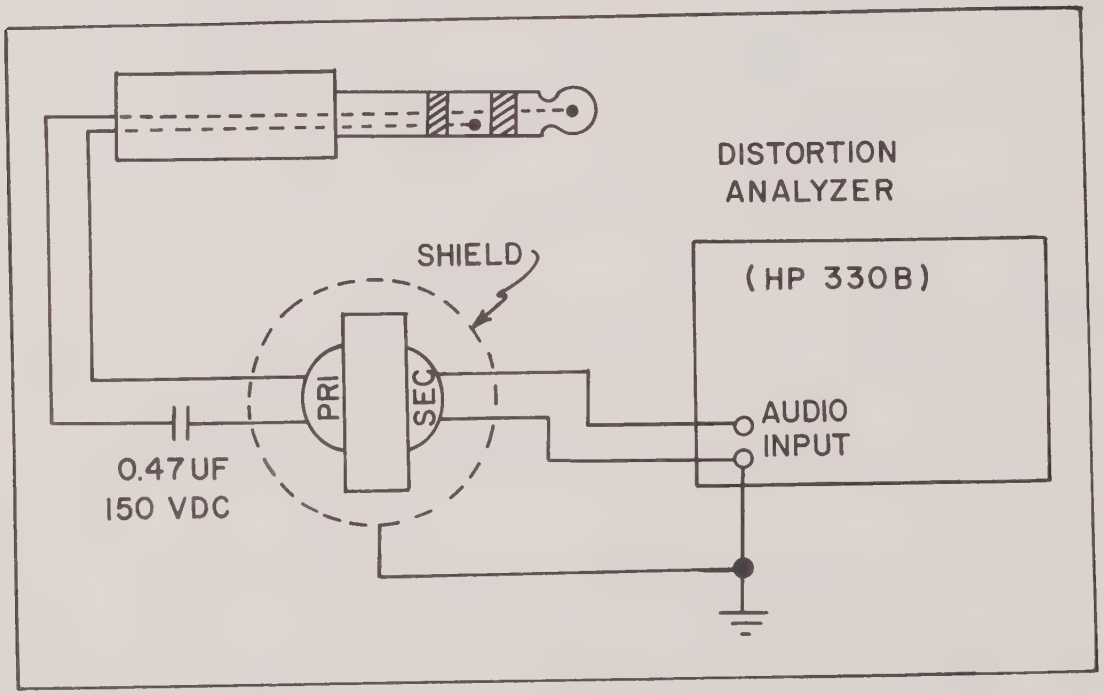


FIG. 2. TEST SETUP FOR DISTORTION MEASUREMENT

F. Rotate balance adjust potentiometer ~~R113~~ R123 until minimum distortion is read on the distortion analyzer. This should be at least 38 db down. While making this adjustment, the deviation must be maintained at 18 Kc. Re-adjustment of the DEVIATION ADJUST controls may be required to maintain the 18 Kc deviation.

G. Connect a frequency counter across the distortion analyzer input connectors.

H. Turn the PFM-2 function switch to INT. MOD. and adjust potentiometer R106 for a counter reading of 1000 ± 2 cps.

I. Using potentiometer R113, adjust the distortion to be at least 36 db down. Maintain a deviation of 18 Kc in the same manner as in step F.

J. Turn the PFM-2 function switch to CAL. and adjust potentiometer R104 for a counter reading of 2080 ± 4 cps.

K. Check that distortion is at least 36 db down. Re-check this value on all three positions of the function switch.

4-3 FIVE MEGACYCLE OSCILLATOR ADJUSTMENT

NOTE: Before performing the following procedure, the bias voltages on transistors Q201 and Q202 should be checked. Correct voltages are listed in Sections 5-4.

A. Using the PFM-2 as a frequency modulator, perform steps A through E of the operating instructions in Section 2-1.

B. Place the 5 MC. ADJ. knob to the center position.

C. Adjust glass variable capacitor C204 for an MCM-5 meter reading of zero frequency. A non-metallic screwdriver must be used.

D. Check that the range of control of the 5 MC. ADJ. knob is at least 500 cps on either side of zero.

E. Turn the MCM-5 function switch to SIG. LEVEL.

F. Using the non-metallic screwdriver, adjust ceramic capacitor C201 for a peak reading on the MCM-5 meter. The peak reading should be into the green area of the meter scale.

4-4 FIVE MEGACYCLE BANDPASS FILTER ADJUSTMENTS

There are six ceramic variable capacitors in the filter printed circuit board subassembly. These capacitors are adjusted at the factory and should not require further adjustment for an indefinite period.

NOTE: UNDER NO CIRCUMSTANCES SHOULD ADJUSTMENT OF THE FIVE MEGACYCLE BANDPASS FILTER CAPACITORS BE ATTEMPTED IN THE FIELD.

4-5 POWER SUPPLY ADJUSTMENTS

There are no adjustments required for the -15 volt DC power output. If this voltage falls outside of the limits of -14.5 to -15.5, component aging or a component failure is the cause.

SECTION 5

REPAIR

5-1 GENERAL TROUBLESHOOTING

If the PFM-2 fails to operate, or if a malfunction has caused obvious incorrect operation, the trouble can usually be isolated to one of the four basic circuits by merely observing the symptoms or by performing a simple check with the unit connected to the MCM-5. The following outline will aid the operator in determining the general cause of a malfunction. Once the malfunction is isolated to a basic circuit, the faulty component can be located by using standard signal tracing and voltage and resistance measurement procedures. Normal quiescent biasing voltages for all transistors and test point voltages, are provided in Section 5-4.

A. POWER SUPPLY

The first check is for a blown fuse. If the fuse is blown, the front panel indicator lamp will not illuminate when the PFM-2 is installed in the MCM-5. Faulty fuses should be replaced with 2 AMP. SLO BLO fuses. The fuse holder is on the rear of the unit.

NOTE: A blown fuse may be indicative of a circuit malfunction. Continuous blowing of fuses will therefore require detailed troubleshooting within the power supply circuit.

B. FIVE MEGACYCLE OSCILLATOR

A simple check for proper operation of the five megacycle oscillator is to place the MCM-5 funtion switch to the SIG. LEVEL position and observe the meter. Indication should be in the green. No reading, or a reading not in the green shows that the five megacycle oscillator is not functioning, or functioning improperly. Poor operation of the oscillator may be corrected by performing the adjustment procedure outlined in Section 4-3. However, if troubleshooting is required, the power supply and the transistor bias voltages should be checked against the correct levels listed in Section 5-4. If the voltages are correct, the fault is likely to be in the AFC circuit.

To check the AFC, read the voltage at test points TP-C and TP-D with a high impedance voltmeter or VTVM. Correct voltages are listed in Section 5-4.

C. AUDIO OSCILLATOR

The output of the internal audio oscillator can be observed by connecting an oscilloscope to the SCOPE output jacks on the MCM-5. Placing the PFM-2 function switch to INT. MOD. provides the 1000 cps audio and placing it to the CAL. position provides the 2080 cps signal. The DEVIATION ADJUST potentiometers provide control of the audio signal amplitude. If one or both of the audio signals are not present, or appear to be improper, the audio oscillator is faulty. Performing the calibration procedure outlined in Section 4-2, should correct the fault.

D. FIVE MEGACYCLE BANDPASS FILTER

A malfunctioning five megacycle bandpass filter is indicated if there is no DC output, but the PFM-2 is otherwise functioning normally. If the filter malfunctions, troubleshooting should not be attempted, since special test equipment is usually required. (See Section 4-4). The filter circuit is constructed on a small printed circuit board and attached to the main board by five wires soldered in place. The filter board should be removed and returned to the factory. A replacement filter will be provided at a nominal charge.

5-2 CABINET REMOVAL AND REPLACEMENT

The following procedure is recommended for cabinet removal and replacement:

A. Unplug the PFM-2 from the MCM-5.

B. Remove the 12 phillips-head screws from the top, back and sides of the instrument.

C. Slide the cover back from the front panel until the instrument is completely exposed.

D. To assemble, reverse the above procedure.

5-3 TYPICAL TRANSISTOR AND TEST POINT VOLTAGES

A. Pre-adjustments necessary:

1. Zero the five megacycle oscillator in the MCM-5 with the PFM-2 disconnected.

2. Zero the PFM-2 with the MCM-5 selector switch in the ± 10 Kc position.

3. Turn the selector switch in the PFM-2 to EXT. MOD.

4. Turn the DEVIATION ADJUST knob on the PFM-2 fully counterclockwise.

B. All voltages are DC unless otherwise noted.

C. Voltage readings may vary from instrument to instrument, depending upon input line voltage, transistor variances, etc.

D. These average readings are obtained from a high input resistance type VTVM. Line voltage to the MCM-5 is 117 volts AC.

F. Pin number 2 of transformer T301 is the instrument ground and all voltages are read with respect to this point.

G. When reading test point A (TP-A), place selector switch to the CAL. position.

5-4 TYPICAL VOLTAGE READINGS PFM-2

Circuit Reference	Transistor Type	Transistor Function	Bias Voltage (DC) Base	Emitter	Collector
Q-101	2N1304	emitter-follower for audio oscillator	-5.5	-5.7	0
Q-102	2N1516	amplifier for phase shift oscillator	-5.6	-5.4	-8.9
Q-103	2N404	deviation adjust amplifier	-0.2	-.02	-4.2
Q-201	2N1516	5 mc oscillator	-5.3	-5.2	-10.7
Q-202	2N1516	5 mc amplifier	-4.1	-3.8	-10.7
Q-301	2N1376	series voltage regulator	-15.6	-15.4	-19.5
Q-401	2N1516	5 mc filter amplifier	-1.8	-2.0	-11.1

T-301 Pin 1 6.4 vac Pin 3 17.0 vac Pin 5 17.0 vac

Test Point A 2.1 vac Mod. Sel. to CAL. position

Test Point B -11.8 DC

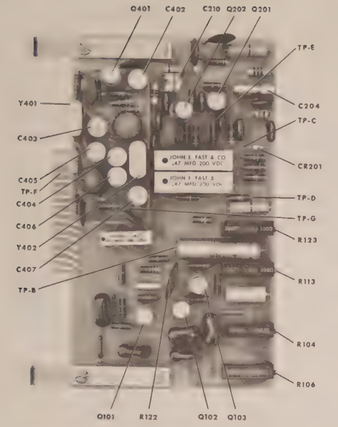
Test Point C 39 DC

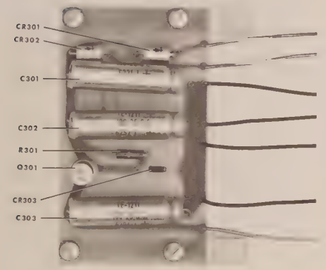
Test Point D 36 DC

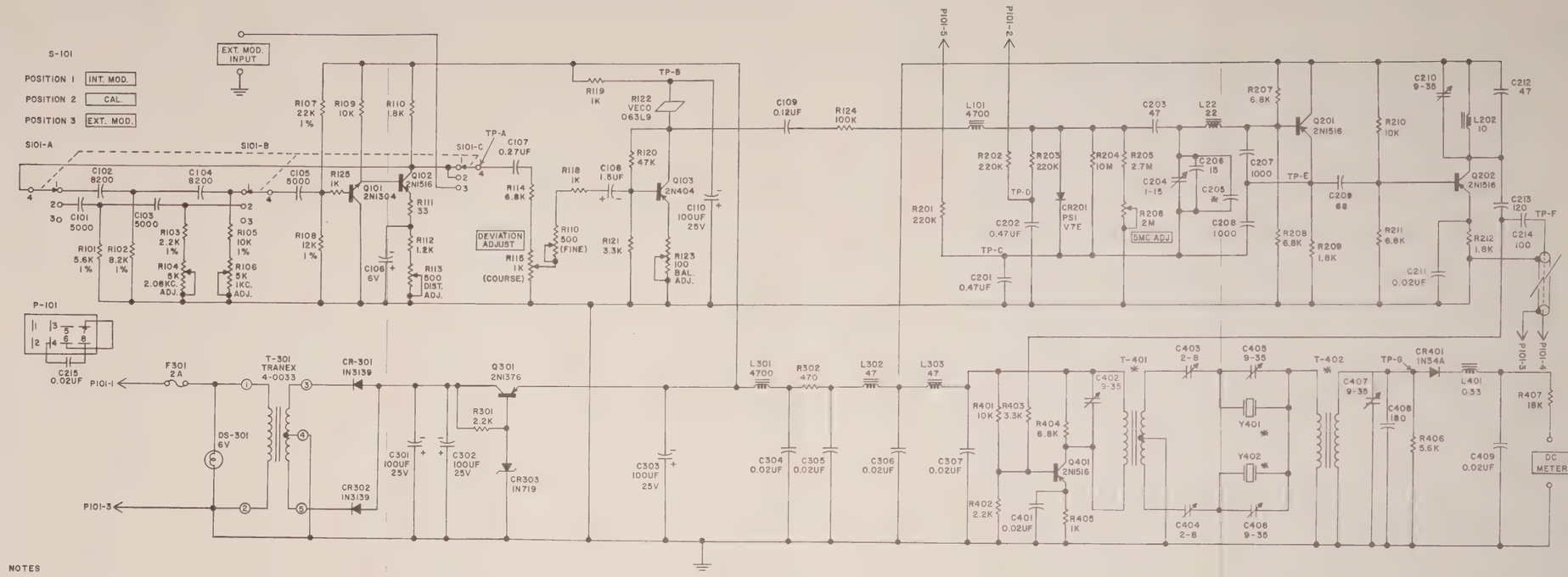
Test Point E .08 vac

Test Point F .78 vac

Test Point G 1.8 vac







NOTES

1. UNLESS OTHERWISE NOTED: ALL RESISTORS ARE IN OHMS (5%-1/2W)
   ALL INDUCTORS ARE IN MICROHENRIES (10%)
   ALL CAPACITORS ARE IN PICOFARADS (10%-200V)
2. * INDICATES FACTORY SELECTED COMPONENTS
3. ▭ INDICATES PANEL CONTROL

THIS DRAWING IS INTENDED FOR THE OPERATION AND MAINTENANCE OF CUSHMAN ELECTRONICS EQUIPMENT AND IS NOT TO BE USED OTHERWISE OR REPRODUCED WITHOUT WRITTEN CONSENT FROM CUSHMAN ELECTRONICS, INC.

MODEL PFM-2 SCHEMATIC

REPLACEABLE PARTS

CKT. REF.	DESCRIPTION	C/E STOCK #	MANUFACTURER	TOT. QTY.
C101	Capacitor: fixed, mica 5000 pf ± 5%, 100 vdcw	1002-0075	Electromotive Mfg. Co.	3
C102	Capacitor: fixed, mica 8200 pf ± 5%, 100 vdcw	1002-0076	Electromotive Mfg. Co.	2
C103	Same as C101			
C104	Same as C102			
C105	Same as C101			
C106	Capacitor: electrolytic 180 mfd ± 10%, 6 vdcw	1013-0002	Texas Instruments, Inc.	1
C107	Capacitor: fixed, mylar .27 mfd ± 10%, 200 vdcw	1008-0004	Erie Resistor Corp.	1
C108	Capacitor: electrolytic 1.5 mfd ± 10%, 35 vdcw	1013-0001	Texas Instruments, Inc.	1
C109	Capacitor: fixed, mylar .12 mfd ± 10%, 200 vdcw	1008-0003	John E. Fast & Co.	1
C110	Capacitor: electrolytic 100 mfd ± 10%, 25 vdcw	1013-0003	Sprague Electric Co.	4
C201	Capacitor: fixed, mylar .47 mfd ± 5%, 200 vdcw	1008-0005	John E. Fast & Co.	2
C202	Same as C201			
C203	Capacitor: fixed, mica 47 pf ± 5%, 500 vdcw	1002-0012	Electromotive Mfg. Co.	2
C204	Capacitor: trimmer P.C.B. Type 1-18 pf	1001-0007	J.F.D. Electronics Corp., Brooklyn, N.Y.	

REPLACEABLE PARTS (CONT.)

CKT. REF.	DESCRIPTION	C/E STOCK #	MANUFACTURER	TOT. QTY.
C205	Capacitor: fixed, mica factory selected 15 pf ± 5%, 500 vdcw	1002-0001	Electromotive Mfg. Co.	1
C206	Capacitor: fixed, ceramic 15 pf ± 2%, 1200 V N330	1005-0012	Centralab Division of Globe Union	1
C207	Capacitor: fixed, mica 1000 pf ± 5%, 500 vdcw	1002-0015	Electromotive Mfg. Co.	2
C208	Same as C207			
C209	Capacitor: fixed, mica 68 pf ± 5%, 500 vdcw	1002-0013	Electromotive Mfg. Co.	1
C210	Capacitor: variable, ceramic 9-35 pf 200 vdcw	1001-0005	Erie Resistor Corp.	1
C211	Capacitor: fixed, ceramic .02 mfd ± 20%, 600 vdcw	1005-0004	Erie Resistor Corp.	8
C212	Same as C203			
C213	Capacitor: fixed, mica 120 pf ± 5%, 500 vdcw	1002-0010	Electromotive Mfg. Co.	1
C214	Capacitor: fixed, mica 100 pf ± 5%, 500 vdcw	1002-0011	Electromotive Mfg. Co.	1
C215	Same as C211			
C301	Same as C110			
C302	Same as C110			
C303	Same as C110			
C304	Same as C211			
C305	Same as C211			
C306	Same as C211			

REPLACEABLE PARTS (CONT.)

CKT. REF.	DESCRIPTION	C/E STOCK #	MANUFACTURER	TOT. QTY.
C307	Same as C211			
C401	Same as C211			
C402	Capacitor: variable, ceramic 9-35 pf 200 vdcw	1001-0006	Erie Resistor Corp.	4
C403	Capacitor: variable, ceramic 2-8 pf 200 vdcw	1001-0004	Erie Resistor Corp.	2
C404	Same as C403			
C405	Same as C402			
C406	Same as C402			
C407	Same as C402			
C408	Capacitor, fixed, mica 180 pf ± 5% 500 vdcw	1002-0005	Electromotive Mfg. Co.	1
C409	Same as C211			
CR201	Diode: silicon, V7E	1281-0005	Pacific Semiconductor, Inc.	1
CR301	Diode: Silicon, 1N3193	1281-0003	Radio Corp. of America Semiconductor Division	1
CR302	Same as CR301			
CR303	Diode: silicon, 1N719	1281-0004	Pacific Semiconductor, Inc.	1
CR401	Diode: Germanium, 1N34AS	1282-0003	Sylvania Electric Prod. Inc. Semiconductor Division	1

REPLACEABLE PARTS (CONT.)

CKT. REF.	DESCRIPTION	C/E STOCK #	MANUFACTURER	TOT. QTY.
DS301	Lamp: 6V	2870-0003	General Electric Co.	1
F301	Fuse: 2 amp. 3 ag	1955-0002	Littlefuse, Inc.	1
J101	Binding Post; Assy.	2595-0001	Herman Smith, Inc.	2
J102	Same as J101			
L101	Choke: molded coil 4700 mh 5%	1585-0006	Delevan Electronics Corp.	1
L201	Choke: molded coil 22 mh 10%	1585-0009	Delevan Electronics Corp.	1
L202	Choke: molded coil 10 mh 10%	1585-0008	Delevan Electronics Corp.	1
L301	Same as L101			
L302	Choke: molded coil 47 mh 5%	1585-0010	Delevan Electronics Corp.	2
L303	Same as L302			
L401	Choke: molded coil .33 mh 20%	1585-0007	Delevan Electronics Corp.	1
P101	Connector: 8 pin male	2535-0004	Cinch Jones Mfg. Co.	1
Q101	Transistor: Germanium 2N1304	1272-0003	Texas Instruments, Inc.	1
Q102	Transistor: Germanium 2N1516	1272-0001	Amperex Electronic Co.	4
Q103	Transistor: Germanium 2N404	1272-0002	Texas Instruments, Inc.	1
Q201	Same as Q102			

REPLACEABLE PARTS (CONT.)

CKT. REF.	DESCRIPTION	C/E STOCK #	MANUFACTURER	TOT. QTY.
Q202	Same as Q102			
Q301	Transistor: Germanium 2N1376	1272-0004	Texas Instruments, Inc.	1
Q401	Same as Q102			
R101	Resistor: fixed, deposited carbon 5620 ohms ± 1% 1/4 W	1075-0013	Allen-Bradley Co.	1
R102	Resistor: fixed, deposited carbon 8250 ohms ± 1% 1/4 W	1075-0014	Allen-Bradley Co.	1
R103	Resistor: fixed, deposited carbon 2210 ohms ± 1% 1/4 W	1075-0010	Allen-Bradley Co.	1
R104	Resistor: variable wirewound 5000 ohms ± 10% 1/2 W	1215-0003	Bourns, Inc. Trimpot Division Riverside, Calif.	2
R105	Resistor: fixed, deposited carbon 10,000 ohms ± 1% 1/4 W	1075-0009	Texas Instruments, Inc.	1
R106	Same as R104			
R107	Resistor: fixed, deposited carbon 22,100 ohms ± 1% 1/4 W	1075-0012	Texas Instruments, Inc.	1
R108	Resistor: fixed, deposited carbon 12,100 ohms ± 1% 1/4 W	1075-0011	Texas Instruments, Inc.	1
R109	Resistor: fixed, composition 10,000 ohms ± 5% 1/2 W	1067-1035	Allen-Bradley Co.	3
R110	Resistor: fixed, composition 1800 ohms ± 5% 1/2 W	1067-1825	Allen-Bradley Co.	3

REPLACEABLE PARTS (CONT.)

CKT. REF.	DESCRIPTION	C/E STOCK #	MANUFACTURER	TOT. QTY.
R111	Resistor: fixed, composition 33 ohms ± 5% 1/2 W	1067-3305	Allen-Bradley Co.	1
R112	Resistor: fixed, composition 1200 ohms ± 5% 1/2 W	1067-1225	Allen-Bradley Co.	1
R113	Resistor: variable wirewound 500 ohms ± 10% 1/2 W	1215-0002	Bourns, Inc. Trimpot Division Riverside, Calif.	1
R114	Resistor: fixed, composition 6800 ohms ± 5% 1/2 W	1067-6825	Allen-Bradley Co.	5
R115/ R116	Resistor: variable wirewound 500 ohms 1000 ohms Dual ± 10% 1 W	1204-0001	CTS Corp.	1
R118	Resistor: fixed, composition 1000 ohms ± 5% 1/2 W	1067-1025	Allen-Bradley Co.	4
R119	Same as R118			
R120	Resistor: fixed, composition 47,000 ohms ± 5% 1/2 W	1067-4735	Allen-Bradley Co.	1
R121	Resistor: fixed, composition 3300 ohms ± 5% 1/2 W	1067-3325	Allen-Bradley Co.	2
R122	Varistor, 1 W	1254-0001	Victory Engineering	1
R123	Resistor: variable wirewound 100 ohms ± 10% 1/2 W	1215-0001	Bourns, Inc. Trimpot Division Riverside, Calif.	1
R124	Resistor: fixed, composition 100,000 ohms ± 5% 1/2 W	1067-1045	Allen-Bradley Co.	1
R125	Same as R118			
R201	Resistor: fixed, composition 220,000 ohms ± 5% 1/2 W	1067-2245	Allen-Bradley Co.	3

REPLACEABLE PARTS (CONT.)

CKT. REF.	DESCRIPTION	C/E STOCK #	MANUFACTURER	TOT. QTY.
R202	Same as R201			
R203	Same as R201			
R204	Resistor: fixed, composition 10 megohms ± 5% 1/2 W	1067-1065	Allen-Bradley Co.	1
R205	Resistor: fixed, composition 2.7 megohms ± 5% 1/2 W	1067-2755	Allen-Bradley Co.	1
R206	Resistor: variable, composition 2 megohms ± 20% 2W	1203-0016	Allen-Bradley Co.	1
R207	Same as R114			
R208	Same as R114			
R209	Same as R110			
R210	Same as R109			
R211	Same as R114			
R212	Same as R110			
R301	Resistor: fixed, composition 2200 ohms ± 5% 1/2 W	1067-2225	Allen-Bradley Co.	2
R302	Resistor: fixed, composition 470 ohms ± 5% 1/2 W	1067-4715	Allen-Bradley Co.	1
R401	Same as R109			
R402	Same as R301			
R403	Same as R121			
R404	Same as R114			
R405	Same as R118			

REPLACEABLE PARTS (CONT.)

CKT. REF.	DESCRIPTION	C/E STOCK #	MANUFACTURER	TOT. QTY.
R406	Resistor: fixed, composition 5600 ohms ± 5% 1/2 W	1067-5625	Allen-Bradley Co.	1
R407	Resistor: fixed, composition 18,000 ohms ± 5% 1/2 W	1067-1835	Allen-Bradley Co.	1
S101	Switch: Rotary, 3P-3T	1851-0004	Oak Mfg. Co.	1
T301	Transformer: 50/60 cycle	1575-0002	Tranex, Inc. Mt. View, Calif.	1
T401	Transformer: toroid	1579-0002	Cushman Electronics, Inc.	1
T402	Transformer: toroid	1579-0001	Cushman Electronics, Inc.	1
Y401	Crystal: 5 Mc	2035-0001	Cushman Electronics, Inc.	1
Y402	Crystal: 4999.8 Kc	2035-0002	Cushman Electronics, Inc.	1
	MISCELLANEOUS			
	Fuse Holder: Type #342012	1965-0001	Littlefuse, Inc. Des Plaines, Ill.	1
	Knob: 3/4" Inner Dual	2780-0006	Kurz-Kasch, Inc.	1
	Knob: 1" Outer Dual	2780-0007	Kurz-Kasch, Inc.	1
	Knob: 1", 5 Mc, adj.	2780-0008	Kurz-Kasch, Inc.	1
	Knob: 1", int. & ext. Mod.	2780-0008	Kurz-Kasch, Inc.	1
	Lamp Assembly: type 107-5030-931-WN	2900-0003	Dialight Corp.	1

WARRANTY

CUSHMAN ELECTRONICS, INC. WARRANTS EACH OF THE INSTRUMENTS OF THEIR MANUFACTURE TO BE FREE FROM DEFECTS IN MATERIAL AND WORKMANSHIP FOR A PERIOD OF ONE YEAR FROM THE DATE OF ORIGINAL PURCHASE. THE FOREGOING IS IN LIEU OF ANY OTHER WARRANTY, EXPRESS, IMPLIED OR STATUTORY. THE COMPANY, UNDER THEIR LIBERAL WARRANTY, WILL REPAIR OR REPLACE ANY INSTRUMENT FOUND DEFECTIVE.

THIS WARRANTY MAY NOT APPLY TO INSTRUMENTS WHICH, IN THE OPINION OF THE COMPANY, HAVE BEEN ALTERED OR MISUSED.

This manual is intended to give the user a comprehensive knowledge of the instrument and its operation or repair. In the event of trouble, study the manual carefully. Most instrument malfunctions can be corrected by the user with a minimum of lost usage time.

For assistance or information of any kind, contact the factory. Give full details of the nature of your problem and include the model and serial number of the instrument.

Should it appear that the instrument needs to be returned to the factory for service or recalibration, let us know. Shipping instructions will be promptly given to you. There will be no charge for repair on instruments within the one year warranty other than transportation costs after 90 days of ownership. Estimates of charges for non-warranty or any other service will be supplied by the factory upon request before work is begun and such work will be done on an actual cost basis only.

CLAIM FOR DAMAGE IN SHIPMENT

Your instrument should be inspected and tested as soon as it is received. The instrument is insured for safe delivery. If the instrument is damaged in any way or fails to operate properly, file a claim with the carrier or, if insured separately, with the insurance company.

. . . . . .

We sincerely pledge our immediate and fullest cooperation to all users of our precision electronic instruments.

PLEASE ADVISE US IF WE CAN ASSIST YOU IN ANY MANNER.

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Sunnyvale, California

MP MASTER
MA31805